



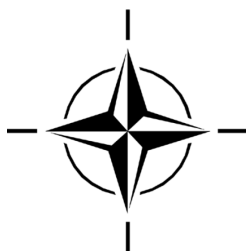
STO TECHNICAL REPORT

TR-HFM-212

Advancements in Distributed Learning (ADL) Environment in Support of Transformation

(Progrès en apprentissage distribué (ADL)
à l'appui de la transformation)

This report documents the findings of Task Group 212. The primary objective of this Task Group was to explore an agile, open ADL framework for content and infrastructure that can be leveraged for global collaboration across NATO, PfP, MD and other Coalition Partners. Additionally, to explore the continued effectiveness of this approach, as well as methods to assess and track learner success while utilizing advanced distributed learning technologies (i.e., conventional and emerging).



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The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses.

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List of Abbreviations

ACT	Allied Command Transformation
ADL	Advanced Distributed Learning
APG	Airplane General
API	Application Program Interface
CBI	Computer-Based Instruction
CBT	Computer-Based Training
CORDRA	Content Object Repository Registration/Resolution Architecture
CTiP	Combating Trafficking in Persons
CWP	Coalition Warfare Program
DISAM	Defense Institute of Security Assistance Management
DL	Distribution Learning
DoD	Department of Defense
DTIC	Defense Technical Information Center
EPSS	Electronic Performance Support System
FY	Fiscal Year
HFM	Human Factors and Medicine (Panel)
HLA	High-Level Architecture
HR	Human Resources
I/ITSEC	Interservice/Industry Training, Simulation, and Education Conference
ICW	Interactive Courseware
IETM	Interactive Electronic Technical Manual
IMI	Interactive Multi-media Instruction
IMIS	Integrated Maintenance Information System
IMSPDB	International Military Student Pre-Departure Brief
iOS	Apple's computers' proprietary mobile operating system (previously iPhone OS)
IT&ED	Individual Training and Educational Development
ITEC	International Training and Education Conference
ITS	Intelligent Tutoring System
JKDDC	Joint Knowledge Development and Distribution Capability
JKO	Joint Knowledge Online
K	Kindergarten
LMS	Learning Management System
LRS	Learning Record Store
MD	Mediterranean Dialogue
MLS	Multi-Channel Learning System
MoLE	Mobile Learning Environment
MVLE	Multi-national Virtual Learning Environment
NATO	North Atlantic Treaty Organization
NeL	Navy's e-Learning

NETSAFA	Naval Education and Training Security Assistance Field Activity
NTG	NATO Training Group
NTIS	National Technical Information Service
ONRL	Office of Naval Research London
OUSD(P&R)	Office of the Undersecretary of Defense for Personnel and Readiness
PDP	Performance Designed Products OR Packet
PfP	Partners for Peace
PfPC	Partnership for Peace Consortium
PIN	Personal Identification Number
POC	Proof Of Concept
R&D	Research and Development
ROI	Return On Investment
RTG	Research Task Group
RUSSEL	Re-Usability Support System for E-Learning
SCETP	Security Cooperation Education and Training Program
SCORM	Sharable Content Object Reference Model
TAD	Technical Activity Description
TAP	Technical Activity Program
TATRC	Telemedicine and Advanced Technology Research Center
TLA	Training and Learning Architecture
TO	Technical Order
ToR	Terms of Reference
TR	Technical Report
US/USA	United States of America
xAMP	x=cross platform, Apache, MySQL and PHP Apache
xAPI	Extensive Application Program Interface

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Advancements in Distributed Learning (ADL) Environment in Support of Transformation (STO-TR-HFM-212)

Executive Summary

Multi-national partners identified the need for a number of technology advancements and the need to address current and future education and training shortfalls. It was recommended to review the ADL needs of NATO, PfP, MD, and other Coalition Partners and determine what advancements were available and which ones were undergoing research and development, to leverage global best practices of ADL to improve readiness of military and civilian personnel.

The main objective of RTG HFM-212 was to identify and explore operational needs and technology capabilities for an agile, open ADL framework for content and infrastructure that can be leveraged for global collaboration across NATO, PfP, MD, and other Coalition Partners. Additionally, to explore the continued effectiveness of the ADL approach and its capabilities to assess and track learner success while utilizing advanced distributed learning technologies (i.e., conventional, traditional and emerging).

RTG HFM-212 enjoyed continual success in reaching its stated objectives. It utilized an existing NATO infrastructure, actively collaborated with other NATO assets (e.g., the NATO Training Group and the PfP Consortium), and built a transition path toward the delivery of its work to NATO school houses. By accomplishing the RTG goals of creating and strengthening partnerships among 24 key Partner Nations, RTG HFM-212 has contributed sizable technology awareness as well as real capabilities to the NATO education and training communities.

A number of important projects were motivated by the efforts of this RTG. These projects are described in Section 6.0. These projects have the potential for large-scale use by NATO and Partner Nations. The way ahead for research in this area is reflected in the proposed, but unfunded, Multi-channel Learning System (MLS) project. Where this project focused on identifying the best methods for providing distance education for international military students preparing for resident training in the U.S., its transition to the NTG IT&ED allows it to continue contributing to NATO education and training schoolhouses. Through this broad collaboration within the Alliance, RTG HFM-212 was able to:

- 1) Develop a capability that ensures International Military Student Pre-Departure Brief (IMSPDB) students have a positive and successful experience in the U.S. along with their U.S. counterparts;
- 2) Identify the best methods for providing distance education for international military students; and
- 3) Evaluate the effectiveness of multiple learning formats to support Security Cooperation Education and Training Program (SCETP) requirements.

Finally, RTG HFM-212 initiated application of ADL capabilities in the medical and health sciences community via its sponsor, the NATO Human Factors and Medicine Panel.

Progrès en apprentissage distribué (ADL) à l'appui de la transformation (STO-TR-HFM-212)

Synthèse

Les partenaires des différents pays ont remarqué qu'un certain nombre de progrès technologiques étaient nécessaires et qu'il fallait corriger des lacunes actuelles et à venir en matière d'éducation et de formation. Il a été recommandé d'examiner les besoins d'ADL de l'OTAN, du PpP, du DM et des autres partenaires de coalition et de déterminer les avancées disponibles et celles faisant l'objet de recherche et développement, afin de tirer parti des meilleures pratiques mondiales d'ADL pour améliorer l'état de préparation du personnel militaire et civil.

Le principal objectif du RTG HFM-212 était d'identifier et d'étudier les besoins opérationnels et les capacités technologiques en vue d'un cadre d'ADL agile et ouvert qui offre un contenu et une infrastructure permettant une collaboration mondiale dans l'ensemble de l'OTAN, du PpP, du DM et des autres partenaires de coalition. Il s'agissait de plus d'étudier l'efficacité continue de la démarche d'ADL et ses capacités à évaluer et suivre la réussite des élèves, tout en utilisant des technologies d'apprentissage avancées et réparties (autrement dit, classiques, traditionnelles et émergentes).

Le RTG HFM-212 a constamment réussi à atteindre les objectifs qui lui avaient été assignés. Le RTG HFM-212 a utilisé une infrastructure existante de l'OTAN, a collaboré activement avec d'autres éléments de l'OTAN (tels que le Groupe OTAN pour l'entraînement et le consortium du PpP) et a ouvert la voie à la transmission de ses travaux aux écoles de l'OTAN. En atteignant les objectifs qui lui avaient été attribués, à savoir la création et le renforcement des partenariats entre 24 pays partenaires essentiels, le RTG HFM-212 a fourni de réelles capacités et une connaissance mesurable de la technologie aux communautés de l'enseignement et de la formation.

Un certain nombre de projets importants ont été motivés par les travaux de ce RTG. Ils sont décrits à la section 6.0. L'OTAN et ses pays partenaires peuvent utiliser ces projets à grande échelle. La marche à suivre pour la recherche dans ce domaine se reflète dans le projet de système d'apprentissage multicanal (*MLS, Multi-channel Learning System*) proposé, mais non financé. Alors que le présent projet s'est concentré sur l'identification des meilleures méthodes d'enseignement à distance pour les élèves militaires internationaux se préparant à un internat aux Etats-Unis, sa transition vers le NTG IT&ED lui permet de continuer à contribuer à l'enseignement et aux écoles de formation de l'OTAN. Par le biais de cette vaste collaboration au sein de l'Alliance, le RTG HFM-212 a :

- 1) Développé une capacité qui garantit que les élèves suivant le stage pré-départ *International Military Student Pre-Departure Brief (IMSPDB)* bénéficient d'une expérience positive et réussie aux Etats-Unis, aux côtés de leurs homologues américains ;
- 2) Identifié les meilleures méthodes d'enseignement à distance pour les élèves militaires internationaux ;
et
- 3) Evalué l'efficacité des multiples formats d'apprentissage à l'appui des exigences du *Security Cooperation Education and Training Program (SCETP)*.

Enfin, le RTG HFM-212 a commencé à appliquer les capacités ADL dans la communauté médicale et des sciences de la santé par le biais de son commanditaire, la Commission sur les facteurs humains et la médecine de l'OTAN.

ADVANCEMENTS IN DISTRIBUTED LEARNING (ADL) ENVIRONMENT IN SUPPORT OF TRANSFORMATION

1.0 ORIGIN OF RTG HFM-212

1.1 Background

International advancements in Distributed Learning (DL) have accelerated over the past decades to meet continuing user needs. These needs often responded to technological advances in networking, computer science, learning science, and the knowledge, experience, and expectations of burgeoning user populations. Building on technological advances, the USA and its multi-national learning technology colleagues encouraged the NATO Alliance in the 1990s to emphasize distributed learning as a means for PfP Nations to reach out via communications and collaborations.

NATO's work in distributed learning quickly took advantage of the rapidly developing Advanced Distributed Learning (ADL) initiative in the USA. One of the major issues they faced was how to collaborate and communicate over a computer network that might not exist in many Nations. The Alliance decided to leverage a newly developed PfP computer network as a backbone for early NATO ADL development, collaboration and evaluation of sharable learning content. This decision, which was discussed at NATO/PfP meeting circa 1997 in Paris, France, initiated a new management infrastructure for collaboration and integration of learning courses and technologies. This ADL effort was soon expanded in both content and breadth to what became known as the PfP Consortium. As this enterprise organizational structure grew and matured, it spawned a number of international activities to explore and capitalize on the art of the possible, change the way we learn in general, and enhance NATO and its Alliance partners' mission effectiveness in particular.

It is important to operationally define the major components of ADL. "Learning" in the ADL sense was used as a catch-all designator for education, training, and performance / decision aiding. "Distributed" in ADL signifies learning that can be provided in classrooms with a teacher present, in the field linking together widely dispersed instructors and students, or standing alone with no instructor other than the computer itself. "Advanced" in ADL implies affordable, interactive, adaptive, on-demand instruction delivered using computer technology so that it is available anytime, anywhere.

Empirical research, available as early as the 1960s, suggested the feasibility of ADL capability with its goals of developing and implementing:

- Individualized, tutorial 'learning' (including individualized performance / decision aiding) that can be provided affordably by technology-based learning.
- Technology-based learning that can be more effective and can produce greater return on investment than conventional instructional approaches across many instructional objectives and subject matters.
- Technology-based learning that allows education, training, performance aiding, and decision aiding to be delivered on platforms ranging from hand-held devices, to desk-top computers, to capabilities embedded in operational equipment.

Statistical findings from this research may be summarized by a "Rule of Thirds" discussed in Annex A. It suggests that one can either reduce instructional time to reach instructional goals by about one-third, or increase the skills and knowledge acquired by about one-third while holding instructional time constant.

Development of the Partnership for Peace Consortium (PfPC) was fundamental to NATO ADL. The PfPC is an international security cooperation organization of over 800 defence academies and security studies institutes across 60 countries. Officially founded in 1999 during the NATO Summit in Washington, DC, USA, the PfPC was chartered to promote defence institution building and foster regional stability and security cooperation through multi-national defence education and research, which the PfPC accomplishes via its international network of educators and researchers.

Thus the creation of the NATO ADL RTG HFM-212 was founded on a vision of how and where learning could advance human performance, coordination, and mission effectiveness for the Alliance during the years to come. It was based on the strong foundation established by the PfPC and its infrastructure of Member Nations to focus on education and training as a primary NATO mission. The long-term vision for ADL is an extrapolation from such technological developments as portable, increasingly accessible computing, the global information infrastructure, modular object-oriented architectures, and natural language processing. The march toward devices that might be described as personal learning associates seems inevitable. These portable devices will act as personal accessories for users. They will respond on demand and in real time to user needs for education, training, and performance aiding by assembling relevant objects from the global infrastructure and engaging the user in guided conversations. This approach can substantially enhance the knowledge, skills, and/or problem-solving capabilities of individuals and/or groups of dispersed individuals whose devices are wirelessly linked together.

Based on a PfP initiative, in March 2008, a Multi-national Virtual Learning Environment (MVLE) Proof of Concept was conducted by the Commander Naval Forces Europe/Commander North Africa/Commander SIXTH Fleet. It was based on an emergent requirement to establish an advanced distance/distributed learning program that would assist key regions of Europe and Africa in training future military and civilian leaders. The goal was to create and strengthen partnerships in key Nations. It succeeded far beyond its expectations.

The initial MVLE Proof of Concept Operational Evaluation was held at the Office of Naval Research Global (ONRG) in London, England, with 35 participants from government and commercial organizations from Azerbaijan, Georgia, Germany, Moldova, Romania, the United Kingdom and the United States. By the time the Operational Evaluation had been completed, seventy-two (72) participants from Azerbaijan, Bulgaria, Georgia, Germany, Moldova, Romania, Tadjikistan, the United Kingdom and the United States had participated in an assessment of a technology-sound Advanced Distributed Learning capability.

As a result of this MVLE Proof of Concept Operational Evaluation meeting, multi-national partners identified the need for a number of technology advancements and the need to address current and future education and training shortfalls. It was recommended that the NATO RTO Human Factors and Medical (HFM) Panel establish a Research Technology Group (RTG) to review the ADL needs of NATO, PfP, MD, and other Coalition Partners and determine what advancements were available for immediate use and which ones were undergoing research and development.

Working with NATO Training Group (NTG) leaders in the Individual Training and Educational Development (IT&ED) Working Group, NATO HFM Panel established ET-105 which transitions into RTG HFM-212. This NATO NTG/RTO team has shared and transitioned its knowledge throughout the Alliance with the help of the Allied Command Transformation (ACT) and Mr. Paul Therkettle. Working collaboratively with the NATO Science and Technology Office in Paris, RTG HFM-212 continues to contribute to NATO's Training infrastructure. Some actions and activities now taking place are:

- Defence education curriculum development;
- Education delivery methods (e.g., distributed computer-based learning);

- Foreign policy recommendation papers;
- Information sharing; and
- Coordination of skills and assets.

The Technical Activity Program (TAP) for this Human Factors and Medical (HFM) Research Technology Group (RTG) 212 was approved in 2010 with an end date of December 2013. Final Report was due Fall of 2014. However due to a number of funding, organizational, and resultant travel restrictions, the final report was delayed until the first quarter of 2015.

1.2 Justification (Relevance for NATO)

The significant goal of ADL to NATO is to enable and leverage global best practices of ADL for providing more effectiveness during NATO missions and operations. Through such leveraging, the coalition will be able to improve readiness of military and civilian personnel anywhere and anytime the need arises. ADL topics addressed and discussed by RTG HFM-212 were efficient and interoperable sharing of content, competencies, utilization of emerging learning concepts and technologies to enhance training, and to develop and provide meaningful performance metrics.

This RTG found considerable evidence (data) suggesting that computer technology might be affecting this third revolution. Some key findings from the last three years of RTG HFM-212 meeting can be summarized as follows:

- Although individualized learning tailored to the background and needs of individual students has long been viewed as an imperative, it has also been viewed as unaffordable [40]. With few exceptions, we cannot afford one instructor for every student – an Aristotle for every Alexander. Computer technology can make this imperative affordable. A core argument for ADL, then, is not for technology but for making individualized, tutorial instruction affordable, thereby substantially increasing the efficiency of education and training and our ability to accelerate acquisition of knowledge, skill, and expertise.
- The instructional technologies targeted by ADL have been found to be more effective than typical classroom instruction across many instructional objectives and subject matters.
- ADL is generally less costly, offering greater Return On Investment (ROI) than current instructional approaches, especially when many widely dispersed students must be served.
- ADL allows education, training, performance / decision aiding, and problem solving to be delivered from the same knowledge bases on platforms ranging from hand-held devices, to large desk-top computers, to capabilities embedded in operational equipment.
- This RTG served as the vehicle to maintain ADL STO active and productive within the NATO environment. ADL has succeeded far beyond its expectations and much of its success could be attributed to two closely associated NATO activities. RTG HFM-212 that served as the S&T focus for NATO and the NATO Training Group's working group on Individual Training and Educational Development that served as the schoolhouse application for NATO commands. The many uniformed and civilian government professionals who were active in both these organizations are the strength of ADL's operational research capabilities.

2.0 OBJECTIVES

The Human Factors and Medical (HFM) Panel's research technology effort for ADL has three main objectives:

- 1) To identify and explore operational needs and technology capabilities for an agile, open ADL framework for content and infrastructure that can be leveraged for global collaboration across NATO, PfP, MD, and other coalition partners. This objective became one of the main discussion points for Coalition Warfare Program participants as well as RTG HFM-212. Consensus was varied due to the many differences in each Nation's own programs. It was here that multi-domain collaboration became a valuable asset.
- 2) To actively explore the continued effectiveness of the ADL approach and its capabilities to assess and track learner success while utilizing advanced distributed learning technologies (i.e., conventional, traditional and emerging).
- 3) To deliver a meaningful final technical report that each Nation can use in pursuing its own development and use of distributed learning technologies.

The NATO Training Group's Working Group on Individual Training and Educational Development (IT&ED) has been a major partner and contributor by helping transition the RTG work to in-country schoolhouse applications, and even today it continues to identify and assess how to best implement advances in ADL for NATO training.

Annex A of this report is a summary of research underlying ADL. It was compiled by one of the USA RTG HFM-212 delegates, Dr. J.D. Fletcher, a distinguished scientist at the Institute for Defense Analyses.

3.0 MEMBERSHIP IN THE RTG

Membership in RTG HFM-212 is as follows. Unofficial delegates from the NATO Training Group also greatly contributed to the findings and transition of this technology to the Alliance:

- Canada;
- France;
- Finland;
- Italy;
- Netherlands;
- Norway;
- Sweden;
- Switzerland;
- Ukraine;
- United Kingdom; and
- United States.

Leadership for RTG HFM-212 was provided by its Co-Chairs: Dr. Ray Perez and Dr. Kristy Murray from the United States.

Dr. Murray was also a member of the NATO NTG's IT&ED mentioned earlier. This dual NATO membership greatly enhanced the RTG's ability to stay relevant to the NATO via the ACT and therefore the NATO training and education users.

The NATO HFM RTG Mentor was Mr. Paul Chatelier, United States and the Lead Nation for RTG HFM-212 was the United States.

4.0 PARTICIPATION BY PARTNER NATIONS

There was broad participation by Partner Nations: Open to all PfP, MD and Selected Contact Countries (Australia, Japan, New Zealand and South Korea). Interest and some participation from PfP Nations included Azerbaijan, Finland, Moldova, Romania and Sweden.

5.0 MEETINGS HELD BY RTG HFM-212

- First meeting took place in Venice, Italy June 15-16, 2010.

The agenda consisted of review, discussion, and approval of the Technical Activity Plan (TAP) and the Terms of Reference (ToR) for the proposed HFM-212 RTG.

Dr. Perez the co-chairman of the RTG presented for discussion a list of research topics to be pursued by the RTG. These are:

- Adaptive Instruction (Focused on intelligent tutoring features).
- Adaptive Assessment (a much richer assessment environment than currently found in applications that now conform to ADL's (Shared Content Object Reference Model (SCORM); Blended Learning/ Intelligent Learning Technologies, which combine learning experiences from e-learning and classroom learning with data from each medium made accessible to each form of instruction).
- Learner Data (a rich set of data that describes the learner, used as a basis for adaptive learning).
- Collaboration Environments for both instructors and students to collaborate with their peers.
- Read-Write Learning Management System (LMS) (enables instructors to retrieve data from an LMS and to record data in the LMS from classroom-based instruction and from other Computer-Based Training (CBT) not controlled by the LMS).
- Data Persistence/mining (data from various experiences can be stored, shared, and used in a manner enabling a student/trainee to leave the environment and return exactly where he/she left off).
- Security/authentication (especially important for business models and privacy of trainees).
- Alternative devices/formats (especially for hand-held devices).
- Sequencing logic extensions available to SCORM-conformant courseware by providing a mechanism for plug-and-play distributed learning environments.
- Extend support for simulation-based training by formally adopting High-Level Architecture (HLA) and other modeling and simulation protocols to consistently allow the sharing of performance-related training data.
- Continue investigations to optimize the co-management of training and technical data using standards like S1000D.

- Investigate how (e.g., directive, reflective, explicit, implicit) and when (e.g., real time, after action review) to deliver feedback that will maximize learning from intelligent tutor-enhanced serious games. As discussions concerning learning from immersive serious games began to deal with learning, they led to investigations of the extent to which stories and/or competition enhances learning.

RTG members agreed that these were important topics deserving serious attention and they would serve as the topics to be covered in future RTG HFM-212 meetings. Unfortunately, the time and resources available to the RTG members often limited thorough investigation of these topics.

- RTG HFM-212's Spring 2012 meeting was held in conjunction with the International Training and Education Conference (ITEC) 2012 on May 24, 2012 in London, England. Taking advantage of conference facilities, they met jointly with the NATO Training Group (IT&ED) working group on Individual Training and RTG HFM-212. This meeting identified mobile medical uses and opportunities for joint programs.
- The Spring 2013 meeting was held on 26 February 2013 in the USA at the ADL Laboratory in Orlando, FL, USA. Participants included: Dr. Ray Perez, USA; Dr. Kristy Murray, USA; Mr. Paul Chatelier, USA; Commander Geir Isaksen, NOR; LtCol Rolf Thielmann, DEU; Mr. Bill Railer and Lieutenant-Commander Remi Tremblay, CAN. This meeting focused on a mobile project jointly developed with Canada, Germany, Norway, Poland and the United States. The proof of concept utilized the experience API (developed by the ADL Initiative) to deliver and track content via a mobile device.
- The Fall 2013 meeting was held in conjunction with the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) in Orlando, FL, USA, during December 2013. This meeting identified and coordinated demonstrations including timelines and national responsibilities. It also determined opportunities for lectures on advances in ADL for mobile learning and began to place added emphasis on mobile medical. Due to the success of this meeting, where many members would be meeting anyway, the attendees decided to hold meetings of opportunity with NATO attendees at subsequent I/ITSEC conferences.

6.0 RTG HFM-212 DELIVERABLES

It should be emphasized that these deliverable are the result of the joint, collaborative nature of the RTG. Since the overall goal was collaboration and sharing of resources and opportunities, they were focused on transition to the potential population and emphasized shared deliverables and knowledge.

1) RTG HFM-212 identified training technology requirements and challenges associated with the open ADL framework:

- Improving sustainment training to include just-in-time/on-demand training;
- Conducting web-based team training (to include mission rehearsal);
- Locating clear guidance from leadership on Framework Standards;
- Performing Return-on-Investment analysis;
- Developing common tools and defined processes to assist media selection;
- Overcoming Bandwidth issues;
- Improving synthetic training to permit more dynamic presentation of training material (spanning the current gap between classroom and live training);

- Improving real-world training through simulations and virtual environments to include assessments, tracking, and reporting in these environments; and
 - Upgrading legacy content and systems.
- 2) **Training and Learning Architecture** – The ADL Initiative (USA) is developing an open source framework called the Training and Learning Architecture (TLA). The TLA is an umbrella term encompassing all technologies designed to create a rich environment for online training and learning. A goal of the TLA is to ensure platform neutrality, which will accommodate intermittent or disconnected network scenarios, and the capability to move learning out of the desk-top browser. The four pillars of the TLA will include Experience Tracking, Learner Profiles, Content Brokering, and Competency Networks. At the time of this report only the experience tracking pillar is developed to the extent that it is a usable capability.
- **Experience Tracking** – The Experience API (xAPI) is a suite of web services that allows storage and reporting of learning experiences. Experience tracking can be applied to formal, classroom, eLearning, game, and virtual environments, as well as social and other informal learning experiences. The Learning Record Store (LRS) is the experience tracking and storage component of ADL’s service-based approach to the TLA. The platform-independent LRS design allows flexibility in that it may be a stand-alone service or a complementary component of a traditional LMS. In addition, the LRS allows authorized systems to retrieve previously recorded statements, which enable the development of advanced third-party reporting and data analytics tools. The xAPI also moves beyond the single learner approach, allowing for team-based exercises, collaboration, and direct instructor intervention. This capability enables group learning, formal and informal learning, and social learning (on any device or platform). Any system that “understands” the xAPI can share data. Examples include assessment systems, HR systems, gradebook applications, statistical and reporting systems, data bases being assembled for data mining, etc.
- 3) **Mobile Learning + xAPI Research Project** – Naval Post-Graduate School (USA) Project (2013 – 2014) explores the potential of using ADL’s Experience API (xAPI) to track content delivered outside the Navy’s e-Learning (NeL) Learning Management System (LMS) and to synchronize recorded data with the LMS. This work will include identification of metrics that can be compiled and used beyond basic course completion data.
- 4) **Mobile Learning Environment (MoLE) October 2010 to October 2012:**
- MoLE is a Coalition Warfare Program (CWP) funded, Office of Naval Research London (ONRL) grant to create a reference architecture that enables Joint Knowledge Online (JKO) to support effective mobile learning content.
 - Tribal, Inc. (a British contractor) was responsible for active collaboration with JKO. Through 2012 Tribal assisted with the ongoing transition to further define and develop the m-Learning Suite in accordance with JKO requirements. Unfortunately funding from CWP was not continued so the contractor is no longer working on this program.
 - Design and develop technical solutions to deliver mobile learning content within DoD constraints.
 - A final solution incorporating the MoLE app (for both Android and iOS) and the “data collection” back-end portal/services were delivered for Proof Of Concept (POC). Post-POC, further developments were implemented to the app regarding improved “Network” functionality. Final versions of the apps are now live in the relevant stores.

- Twenty-four Partner Nations participated in this 2-year effort.
 - The m-Learning Suite (v1) went live during August 2012 within the JKO architecture. It demonstrated successful deployment, app store approval, multi-device installations, multi-lingual usage, broad user base. All MoLE mobile content is available to key transition partners in converted format, either as stand-alone media (eBooks, video), as mobile courses (e.g., Combating Trafficking in Persons (CTiP)), as modules within the JKO app, or as free access apps.
 - The CWP MoLE project transitioned into two applications:
 - The Global MedAid App – Enabling worldwide medical use, including the civilian medical community; and
 - The JKO/ADL Mobile Hybrid App – Covering joint and coalition military training.
- 5) **JKO/ADL (Joint Knowledge on Line/ADL) Mobile Project** – One MoLE transition has become JKO/ADL Mobile, which is jointly sponsored by JKO and the ADL Initiative, but also includes Canada, Great Britain, Poland and NATO ACT.

Features of JKO/ADL Mobile are as follows:

- Instructional strategies for mobile learning strategies;
 - Guidance and best practices on mobile learning development;
 - Free App available in Apple and Android App stores;
 - Download and complete courses on mobile device (tablets and phones);
 - Course completions synchronized with JKO desk-top system for tracking and reporting;
 - Downloadable job aids;
 - The latest JKO/ADL news;
 - Access to podcasts, videos, and e-books;
 - Course content segregated by participating partners and PIN; and
 - Public content and news announcements available without PIN.
- 6) **The xAPI International Mobile Pilot (xAMP)** – Phase I was completed by a Norway/US cooperative project in 2013. xAMP Phase I included the creation of an xAPI-enabled mobile learning experience (Rules of Engagement introduction module), deployment of US and Norway Learning Record Stores (LRS), and the determination and implementation of basic tracking, reporting, and analytic requirements.
- Phase II of xAMP includes the following potential requirements:
 - Deploy additional LRSs in participating countries;
 - Identify a multi-national end-user group for pilot testing;
 - Perform a pilot test with the user group including a questionnaire and xAPI data collection;
 - Create analytic and reporting tools to process data collected in the pilot test; and
 - Publish findings.
 - Other potential requirements include:
 - Modification of the Rules of Engagement content to a native mobile app (from HTML5);

- Creation of additional Rules of Engagement modules for inclusion in the pilot test; and
 - LRS synchronization functions to share data between LRSs.
- 7) **Re-Usability Support System for E-Learning (RUSSEL)** – The goal of the RUSSEL project was to improve efficiency in content development through the reuse of existing learning materials. RUSSEL is an out-of-the-box repository and digital library. Instructional design is achieved through a built-in Electronic Performance Support System (EPSS) that is facilitated by easy-to-find/use courseware, content, media files, and SCORM assets. It is completely open source (<https://github.com/adlnet/RUSSEL>).
- 8) **The Multi-Channel Learning System (MLS) Project** – Although, not a direct outcome of the RTG, MLS was stimulated by discussion among members of the RTG and identified by the RTG as having potential for large-scale usage by NATO and Partner Nations. The MLS project was proposed jointly by Naval Education and Training Security Assistance Field Activity (NETSAFA) and the Defense Institute of Security Assistance Management (DISAM). The effort focused on identifying best methods for providing distance education for international military students preparing for resident training in the United States. The goals of the MLS Project were to:
- 1) Ensure that International Military Student Pre-Departure Brief (IMSPDB) students have a positive and successful experience in the US along with their US-counterparts;
 - 2) Identify the best methods for providing distance education for international military students; and
 - 3) Evaluate the effectiveness of using multiple learning formats to support Security Cooperation Education and Training Program (SCETP) requirements.

However, the project was not funded.

7.0 CONCLUSIONS AND SUMMARY

RTG HFM-212 enjoyed continual success in reaching its stated objectives as listed in the TAD/TAP. It must be emphasized that this success was due to a substantial NATO/PDP organizational and policy base as well as a strong working relationship with the NATO Allied Command Transformation (ACT) in Norfolk, VA, USA. With the funding support provided by the CWP (Coalition Warfare Program), the excellent collaboration and data sharing of the MoLE, and joint funding from the US Army Telemedicine and Advanced Technology Research Center (TATRC), RTG HFM-212 is considered an outstanding success. It utilized an existing NATO infrastructure, actively collaborated with other NATO assets (e.g., the NATO Training Group and the PfP Consortium), and built a transition path toward the delivery of its work to NATO schoolhouses. By accomplishing the RTG goals of creating and strengthening partnerships among 24 key Partner Nations, RTG HFM-212 has contributed sizable technology awareness as well as real capabilities to the NATO education and training communities.

A number of important projects were motivated by the efforts of this RTG. These projects were described in Section 6.0. These projects have the potential for large-scale use by NATO and Partner Nations. The way ahead for research in this area is reflected in the proposed, but unfunded, MLS Project. Where this project focused on identifying the best methods for providing distance education for international military students preparing for resident training in the US, its transition to the NTG IT&ED allows it to continue contributing to NATO education and training schoolhouses. Through this broad collaboration within the alliance, RTG HFM-212 was able to:

- 1) Develop a capability that ensures International Military Student Pre-Departure Brief (IMSPDB) students have a positive and successful experience in the US along with their US-counterparts;
- 2) Identify the best methods for providing distance education for international military students; and
- 3) Evaluate the effectiveness of multiple learning formats to support Security Cooperation Education and Training Program (SCETP) requirements.

Finally, RTG HFM-212 initiated application of ADL capabilities in the medical and health sciences community via its sponsor, the NATO Human Factors and Medical Panel.

Annex A – RESEARCH FOUNDATIONS FOR THE ADVANCED DISTRIBUTED LEARNING INITIATIVE

A.0 OVERVIEW

The Advanced Distributed Learning (ADL) Initiative was established by the Office of the Undersecretary of Defense for Personnel and Readiness (OUSD(P&R)) in 1997. Its purpose was to assist the military services in making “learning” (education, training, and performance / decision aiding) available on-demand, anytime and anywhere.

“Learning” in ADL is used as a catch-all designator for education, training, and performance/decision aiding. “Distributed” in ADL signifies learning that can be provided in classrooms with a teacher present, in the field linking together widely dispersed instructors and students, or standing alone with no instructor other than the computer itself. “Advanced” in ADL implies affordable, interactive, adaptive, on-demand instruction delivered using computer technology so that it is available anytime, anywhere.

Empirical research, available as early as the 1960s, suggested the feasibility of ADL and its goals. It has shown that:

- Individualized, tutorial ‘learning’ (including individualized performance / decision aiding) can be provided affordably by technology-based learning.
- Technology-based learning can be more effective and can produce greater return on investment than conventional instructional approaches across many instructional objectives and subject matters.
- Technology-based learning allows education, training, performance aiding, and decision aiding to be delivered on platforms ranging from hand-held devices, to desk-top computers, to capabilities embedded in operational equipment.

Statistical findings from this research may be summarized by a “Rule of Thirds.” It states that application of technology-based learning can reduce the cost of instruction by about one-third. Additionally, it can either reduce instructional time to reach instructional goals by about one-third, or increase the skills and knowledge acquired by about one-third while holding instructional time constant.

The long-term vision for ADL is an extrapolation from such developments as portable, increasingly accessible computing, the global information infrastructure, modular object-oriented architectures, and natural language processing. The march toward devices that might be described as personal learning associates seems inevitable. These devices will act as personal accessories. They will respond on demand to requests for education, training, and performance aiding by assembling relevant objects from the global infrastructure and engaging the user in guided conversations to enhance the knowledge and skills and/or problem-solving capabilities of individuals and/or groups of dispersed individuals whose devices are wirelessly linked together.

A.1 THE REQUIREMENT

About 1.1 million US forces are dispersed across the Continental United States and an additional 1.4 million forces are spread across 50 foreign countries. Individuals in these forces need to be capable of independent thought and action. They also need to be able to continue their training and career growth when they are far removed from military schoolhouses, expert mentors, or others in their own career specialties.

Additional complications arise from the rapid growth in the amount and complexity of information that individuals at all levels must integrate and prioritize. The trend has produced an increasing demand for what Wulfeck and Wetzel-Smith (2008) [51] and Wetzel-Smith and Wulfeck (2010) [49] have described as “incredibly complex tasks.” Today, about 15% of military tasks are abstract, multi-dimensional, non-linear, dynamic, and inter-dependent. The dynamic nature of these tasks and the evolving operational environment require that individuals receive up-to-date training and performance assistance.

Finally, the difficulty of all military tasks is exacerbated by the dispersal of units and the individuals serving within these units. Human decisions and actions must be coordinated within and across teams whose members may be globally dispersed in other Nations, immersed in other cultures, and serving at widely varied command levels. The ability to communicate, coordinate, and perform tasks under these conditions may not guarantee success, but the consequences of its absence are severe.

These operational conditions have created an imperative to ensure that “learning” – education, training, and task, job, and decision aiding – is rapidly available on demand, anytime and anywhere, to uniformed and civilian individuals and teams at all levels of responsibility.

A.2 THE TECHNICAL OPPORTUNITY: A THIRD REVOLUTION IN LEARNING

In response to this requirement, ADL is riding and contributing to a third revolutionary wave in learning. The first revolution in learning occurred about 5,000 years ago, with the invention of writing – the use of graphic tokens to represent syllables of sound. Before the invention of writing, learning activity appears to have been conducted as a tutorial conversation between a learner and a sage, or at least someone who had the knowledge and skills the learner sought to acquire. With writing, a learner could access knowledge and skill without this face-to-face interaction. Writing allowed the content of ideas and instruction to transcend time and place.

The second revolution in learning occurred with the invention of books printed from moveable type – first in China around 1000 A.D. and then in Europe in the mid-1400s [31]. With books, the dissemination of knowledge and skills through writing became scalable. Once content was produced, it could be made widely available and became increasingly inexpensive as printing technology developed. However, with writing and printing, the dissemination of content was passive. It lacked the tutorial interactivity that had been the foundation of learning for the previous 100,000 years or so of human existence.

Enter computer technology, with its ability to adapt rapidly, in real time, to the changing demands, needs, and circumstances of learners and learning. Computer technology allows not just content, but also instructional strategies, techniques, and interactions to become inexpensively ubiquitous and available on demand – anytime, anywhere. It may be fomenting a third revolution in learning. ADL is a response and a contributor to this third revolutionary possibility.

“Learning” in ADL is used as a catch-all designator for education, training, and performance / decision aiding. “Distributed” in ADL is not just another word for distance. It signifies learning that can be provided in classrooms with a teacher present, in the field linking together widely dispersed instructors and students, or standing alone with no instructor other than the computer itself. “Advanced” in ADL implies affordable, interactive, adaptive, on-demand instruction using computer technology so that it can be delivered anytime, anywhere.

The ADL purpose, from its inception, has been to ensure access to the highest quality education, training, and performance/decision aiding tailored to individual needs and delivered cost effectively and anytime/anywhere.

A.3 EVIDENCE: RESEARCH AND DEVELOPMENT (R&D) FOUNDATIONS

What evidence suggests that computer technology might be affecting this third revolution? What have we learned from research on computer uses in instruction? Some key findings can be summarized as follows:

- Although individualized learning tailored to the needs of individual students has long been viewed as an imperative, it has also been viewed as unaffordable [40]. With few exceptions, we cannot afford one instructor for every student – an Aristotle for every Alexander. Computer technology can make this imperative affordable. A core argument for ADL, then, is not for technology but for making individualization affordable.
- The instructional technologies targeted by ADL have been found to be more effective than typical classroom instruction across many instructional objectives and subject matters.
- ADL is generally less costly, offering greater Return On Investment (ROI) than current instructional approaches, especially when many widely dispersed students must be served.
- ADL allows education, training, and performance / decision aiding and problem solving to be delivered from the same knowledge bases on platforms ranging from hand-held devices, to large desk-top computers, to capabilities embedded in operational equipment.

These arguments have been made for the computer-assisted approaches used by ADL for the last 40 – 50 years (e.g., [1], [3], [10], [23], and [42]). They have been repeatedly validated by empirical research and practical experience. Statistical findings from this work have been summarized by a “Rule of Thirds” [15], [16]. This rule states that application of the technologies on which ADL is based reduces the cost of instruction by about one-third. In addition, the application of these technologies can either reduce instructional time to reach instructional goals by about one-third or increase the skills and knowledge acquired by about one-third while holding instructional time constant.

The following sections discuss more specifically the R&D behind these arguments and the Rule of Thirds.

A.4 INDIVIDUALIZATION: TUTORIAL INSTRUCTION

The argument for ADL technology begins with an issue that arises independently from applications of technology. It concerns the effectiveness of classroom instruction, involving one instructor for 20 – 30 (or more) students, compared to individual tutoring, involving one instructor for each student. Empirical results from comparisons of this sort are shown in Figure A-1, adapted from Bloom (1984) [4].

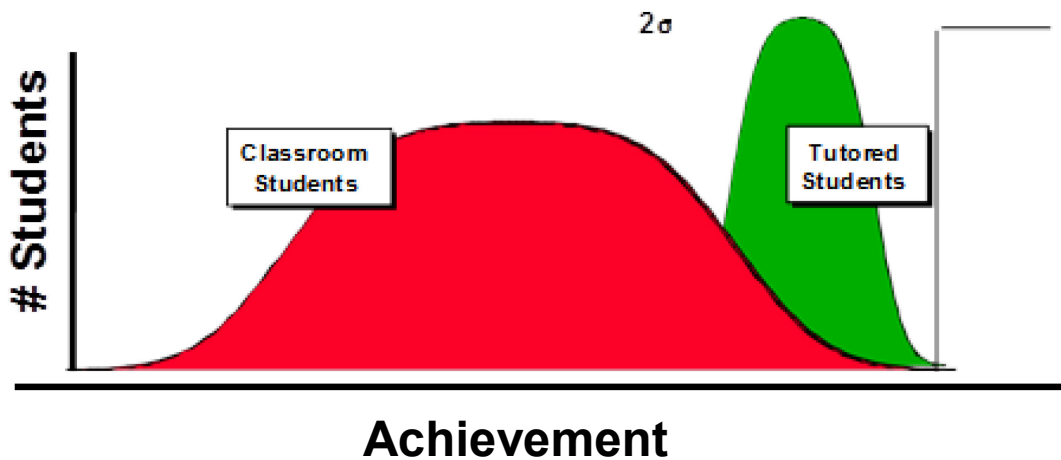


Figure A-1: Individual Tutoring Compared to Classroom Instruction.

Bloom combined findings from three empirical studies that compared tutoring with one-on-many classroom instruction. The result of such comparisons showed the tutored students to have learned more, and the result is not surprising. The surprise is the size of the difference. Overall, as Figure A-1 suggests, the difference was found to be two standard deviations. It suggests that one-on-one tutoring, with instructional time held constant, can raise the performance of mid-level 50th-percentile students roughly to that of 98th-percentile students. These and similar empirical findings suggest that differences between one-on-one tutoring and typical classroom instruction are not only likely but very large.

Most importantly for training applications, the shapes of these distributions support Corno and Snow's (1986) [9] suggestion that the individualization provided by tutorial instruction helps guarantee that all learners reach some basic level of competency.

What accounts for the success of one-on-one tutoring? The research summarized below suggests that it is primarily due to:

- 1) The ability of tutors and their students to engage in many more interactions per unit of time than is possible in a classroom; and
- 2) The ability of tutors to tailor pace, sequencing, and content to the needs, capabilities, goals, interests, and values of individual students.

A.4.1 Interactivity

With regard to the first tutorial capability (the intensity of instructional interaction), Graesser and Person (1994) [27] reported the following:

- Average number of questions by a teacher of a class in a classroom hour: 3.
- Average number of questions asked by a tutor and answered by a student during a tutorial hour: 120 – 145.
- Average number of questions asked by any one student during a classroom hour: 0.11.
- Average number of questions asked by a student and answered by a tutor during a tutorial hour: 20 – 30.

These data show great differences in interactivity and intensity between tutorial and classroom instruction. This level of interactivity, by itself, may account for a substantial portion of the success of tutorial over classroom instruction.

Is this level of interactivity found in instruction using ADL technology? Early studies of computer-assisted instruction in reading and arithmetic found that students in grades K-6 were answering 8 – 10 individually selected and assessed questions each minute [17], [19]. This level of interactivity extrapolates to 480 – 600 such questions an hour if students were to sustain this level of interaction for 60 minutes.

A.4.2 Tailoring Pace, Sequencing, and Content

With regard to the second tutorial capability (tailoring the session content), tutors adjust the content and sequence of instruction to the needs of their students. All these adjustments relate to pace – the rate or speed with which students are allowed to proceed through instructional material.

Many classroom instructors have been struck by the differences in the pace with which their students learn. Their observations are confirmed by research. For instance, consider some findings on the time it takes for different students to reach the same instructional objectives:

- Ratio of time needed by fastest and slowest students to reach mathematics objectives: 4 to 1 [43], [44].
- Overall ratio of time needed by fastest 10% and slowest 10% of K-8 students to reach objectives in a variety of subjects: 5 to 1 [25].
- Ratio of time needed by fastest and slowest undergraduates in a major research university to learn a programming language: 7 to 1 (Private communication, Corbett, 1998).

The differences in the speed with which students learn are not surprising, but, as with tutoring, the magnitudes of the differences are surprising. Although the speed with which different students reach instructional objectives is not independent of ability, research has found that it is most directly keyed to prior knowledge [11], [47]. Students in military education and training bring with them a wide variety of backgrounds and life experiences – often much wider than those found among K-12 students. Adjusting the pace of instruction to their individual needs may be especially important for them.

The challenge this diversity presents to classroom instructors is daunting. Typically, the instructors focus on some of their students and leave the others to fend for themselves. This pattern is especially true in training settings where the primary task is to enable as many learners as possible to cross a specific threshold of knowledge and skill. Technology alleviates this difficulty because it allows each learner to proceed as rapidly or as slowly as needed. Learners can skip what they already know and concentrate on what they need to learn.

The degree to which individualization of sequence and content matters is to some extent addressed by studies comparing individualized branching with fixed-content, linear sequencing. Two of the early studies were performed by Fowler (1980) [21] and Verano (1987) [48].

Both of these researchers used computer-controlled videodisc instruction in their experiments. Fowler compared branched presentations with linear instruction in which precisely the same materials were held to a fixed-content, linear sequence. She reported an effect size of 0.72 (roughly, an improvement from the 50th to 76th percentile) in the ability to operate and locate faults on a movie projector. Verano also compared an interactive, adaptive, branching approach with a strictly linear approach for presenting instructional material in beginning Spanish. He reported an effect size of 2.16 (roughly, an improvement from the 50th to 98th percentile) in end-of-course

knowledge. These two studies, among others, suggest that individualization of sequence and content matters – perhaps a great deal.

A.5 TECHNOLOGY-ASSISTED LEARNING

A.5.1 Time Savings

One of the most stable findings in the comparisons of technology-based instruction and conventional instruction (which uses lecture, text, and experience with equipment (e.g., in the laboratory)) concerns instruction time savings. Table A-1 presents these findings.

Table A-1: Percent Time Savings for Technology-Based Instruction.

Study (Reference)	Number of Studies Reviewed	Average Time Saved (Percent)
(Military Training) [39]	13	54
(Higher Education) [13]	8	31
(Higher Education) [32]	17	34
(Adult Education) [32]	15	24

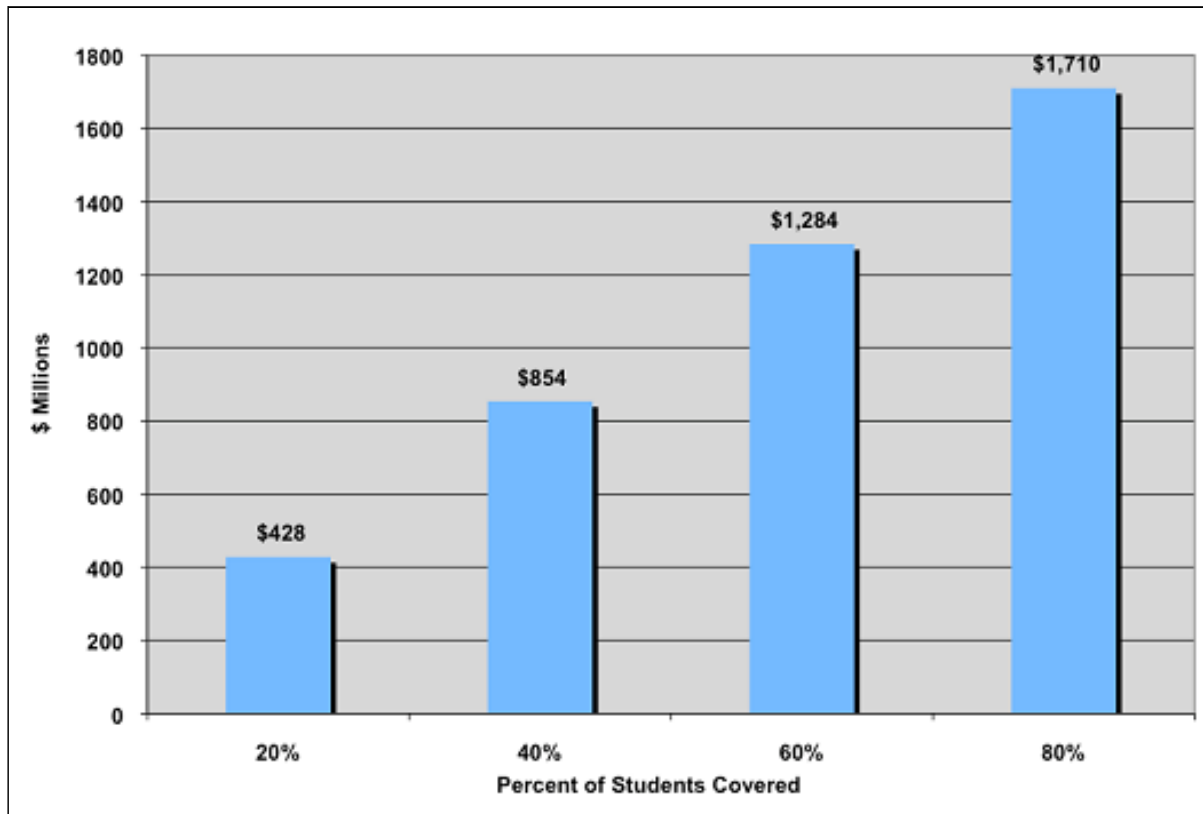
As the table shows, Orlansky and String (1977) [39] reported that reductions in time to reach instructional objectives averaged about 54% in 13 assessments of technology-based military training. Fletcher (1991) [13] reported an average time reduction of 31% in 8 assessments of IMI applied in higher education. Kulik reported average time reductions of 34% in 17 assessments of technology used in higher education and 24% in 15 assessments of adult education [32]. Each of these reviews covered different sets of evaluation studies that compared technology-based instruction and conventional classroom instruction involving lecture, texts, and perhaps laboratory examples. Overall, it seems reasonable to expect that technology-based instruction will reduce by about 30% the time students take to reach a variety of objectives.

A.5.2 Costs

An example of the cost benefits of this reduction in time to learn can be seen in residential, specialized skill training. The DoD spends about \$6.5 billion a year on this training, which is the “schoolhouse” training individuals receive after basic, or initial accession, training. It qualifies individuals for the many technical jobs (e.g., wheeled vehicle mechanics, radar operators, avionics technicians, medical technicians, and so forth) needed to perform military operations. It does not include the costs of aircraft pilot training, officer education, or training provided in military units.

Extrapolated from an earlier analysis by Angier, Fletcher, and Horowitz (1991) [2], Figure A-2 shows the annual reductions in costs that would result if instruction time were reduced by 30% for 20, 40, 60, and 80 % of military personnel who complete residential, specialized skill training each year. For instance, if the DoD reduced by 30% the time to train 20% of the personnel undergoing specialized skill training, it would save about \$428 million per year. If it were to do so for 60% of these personnel, it would save about \$1,284 million per year – or about 20% of the funds allocated for specialized skill training. Specialized skill training is particularly

amenable to the use of ADL technologies. Use of these technologies by 60% of specialized skill trainees is not an unreasonable expectation.



**Figure A-2: Cost Savings (\$2008) in Specialized Skill Training
Assuming a 30% Reduction in Training Time.**

Saving 30% of training time may be a conservative target. Commercial enterprises that develop technology-based instruction for the DoD regularly base their bids on the expectation that they can reduce instructional time by 50%. Noja (1987) [38] has reported time savings as high as 80% with the use of technology-based instruction in training operators and maintenance technicians for the Italian Air Force.

Two other sources of cost savings with ADL technologies are not considered in the Figure A-2 data. First, the cost models used to generate the data in Figure A-2 assume reductions in training time in residential settings but do not take into account using ADL technologies to distribute some of that training to operational units – thereby reducing change of station or temporary duty costs. Second, ADL technologies can be used to simulate expensive equipment, operational environments, and interpersonal situations – thereby not just reducing costs, but also increasing safety, enhancing visualization, and allowing time to be sped up or slowed down as needed for the training.

Perhaps more importantly for military applications, ADL technologies can prepare individuals more quickly for operational duty. In this way, these technologies act as force multipliers by increasing readiness and operational effectiveness without increasing personnel costs.

A.5.2.1 Instructional Effectiveness

Research data suggest that savings from using ADL technologies do not come at the expense of instructional effectiveness. Empirical findings report the opposite. Figure A-3 shows effect sizes from several reviews of studies that compared conventional instruction with technology-based instruction.

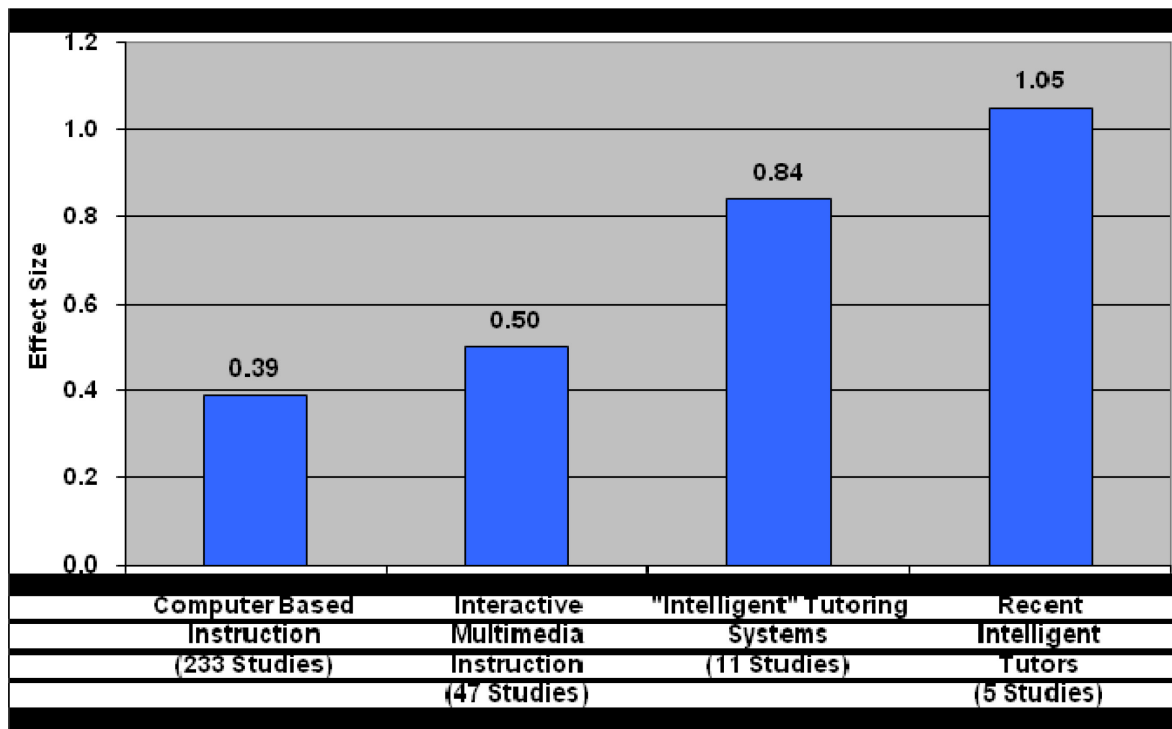


Figure A-3: Some Effect Sizes for Studies Comparing Technology-Based Instruction with More Conventional Approaches.

In Figure A-3, Computer-Based Instruction (CBI) summarizes the results from 233 studies that involved a straightforward application of computer presentations using text, graphics, and some animation, as well as some degree of individualized interaction. The effect size of 0.39 standard deviations suggests, roughly, an improvement of 50th-percentile students to the performance levels of 65th-percentile students.

Interactive Multi-media Instruction (IMI) involves more elaborate interactions adding audio, animation, and video and generally taking advantage of the multi-media effect [20], [34]. These added capabilities evidently increase achievement. They show an average effect size of 0.50, which suggests an improvement of 50th-percentile students to the performance levels of 69th-percentile students.

Intelligent Tutoring Systems (ITSs) involve a capability that has been developing since the late 1960s (e.g., [6] and [41]). In this approach, an attempt is made to directly mimic the one-on-one dialogue that occurs in tutorial inter-actions. A key goal of these systems is to generate computer presentations and responses in real time and on demand as needed or requested by learners. Instructional designers do not need to anticipate and pre-store them. This approach is computationally more sophisticated and more expensive to produce than standard computer-based instruction. However, its cost can be justified by the increase in average effect size to 0.84 standard deviations, which suggests, roughly, an improvement of 50th-percentile students to the

performance levels of 80th-percentile students. As will be discussed later, ROI is much more sensitive to scaling and delivery costs of instruction than to the initial costs to design and develop it.

A selected group of ITSs (“Recent Intelligent Tutors”) was considered just to see how far these systems are progressing. The average effect size of 1.05 standard deviations for these applications is promising. It represents, roughly, an improvement of 50th-percentile students to the performance levels of 85th-percentile students.

The extensive tailoring of instruction that generative, ITSs provide to meet the needs of individual students can only be expected to increase. Such systems may raise the bar – well past Bloom’s 2-Sigma challenge – for the ultimate effectiveness of ADL-based instruction.

A.5.2.2 Student Attitudes

Student attitudes toward instruction can affect its effectiveness and efficiency. Many evaluations of technology-based instruction simply ask students if they prefer it to more conventional classroom approaches. Greiner (1991) [29] reviewed these evaluations and found overall that 70 – 80 % of students who were polled preferred technology-based approaches to other approaches. When students reported that they did not prefer the technology-based approaches, the reasons were usually because of implementation or technical problems with the technology and not the instructional approach itself.

McKinnon, Nolan, and Sinclair (2000) [35] completed a thorough 3-year study of student attitudes toward the use of technology-based learning and productivity tools such as spreadsheets, databases, graphics, desk-top publishing, and statistical processing. The attitudes of the students toward technology use slackened as the novelty of using the technology wore off. However, their attitudes remained positive and significantly more positive than those of students who did not have access to the technology throughout the 3 years of the study.

A.5.2.3 Return On Investment (ROI)

Knowing that we can use ADL technologies to reduce learning time, particularly time to learn journeyman skills such as remembering, understanding, and applying facts, simple concepts, and straight-forward procedures, what might an investment in these technologies return?

One way to answer this question is by applying the findings presented earlier in Figure A-2, which only considered savings. Using the analysis underlying that figure, we can wrap in both the savings and the costs to achieve them using an ROI model. This model simply reduces to the ratio of the net return (savings in this case) to the costs as shown in the following:

$$\frac{\text{Savings} - \text{Costs}}{\text{Costs}}$$

We can begin by assuming (conservatively) a 30% reduction in training time achieved through the use of ADL technologies by (conservatively) 40% of residential specialized training students. From Figure A-2 and the analysis on which it is based [2], these assumptions suggest annual savings of \$854 million. Given this result, the next step is to determine the costs to design, develop, and deliver ADL instruction to 40% of residential specialized skill training students.

Using ADL technology, how much would it cost to render the training needed by 40% of specialized skill students? According to the last published Military Manpower Training Report (2002) [36], the average Specialized Training course length across all four Services was about 57 training days. If that number were reduced by 30%, the training course length would amount to about 40 days. Military personnel in training billets

may be required to perform additional duties, but, assuming 8 hours a day in course training amounts to about 320 hours of training. About 357,700 officers and enlisted personnel completed Specialized Training in FY 2002. Forty percent of that number amounts to 143,080 learners. In effect then, 320 hours of ADL training would have to be produced and then delivered to 143,080 learners.

Estimates to produce an hour of computer-assisted training vary widely and depend on the content, instructional strategy, and pay and allowances for subject-matter experts, “authors,” and computer programmer/analysts. One source of estimates comes from the Joint Knowledge Development and Distribution Capability (JKDDC), which is producing web-based individual training programs for joint assignments and operations. As of May 2008, JKDDC had produced over 200 courses, with more than 65,000 course completions [5]. In the first quarter of FY 2008, the costs for JKDDC to develop an hour of instruction were about \$14,000, and the costs to deliver it were about \$4.

We might then assume that it would cost about \$4.48 million to produce 320 hours of ADL specialized skill training and an additional \$183.14 million to deliver it to 143,080 students. The investment for the first year of this training would cost about \$187.62 million.

Developing and delivering technology-based instruction to 40% of Specialized Skill students (about 143,080 students) would require 30% fewer hours to complete their training – a savings of about 136 hours for each student. Assuming a composite of \$42 per hour in pay and allowances [37], this use of technology-based instruction would amount to $(42 \times 143,080 \times 136) = \817.27 million. Plugging these data and assumptions into an ROI calculation yields:

$$(\$817.27 \text{ M} - \$187.62 \text{ M}) / \$187.62 \text{ M} = \$3.36$$

Under these assumptions, an investment in ADL technology will return about \$3.36 for every dollar invested.

After the first year, the costs to develop the instruction would be reduced to whatever is required to maintain and update the course, but the ROI is not particularly sensitive to development costs. It seems far more sensitive to delivery costs. They are included in this analysis for the delivery of the ADL instruction but not for the classroom instruction it replaces. If the savings in training delivery costs were fully considered in this calculation, the ROI would increase substantially. Also, as suggested earlier, 30% time savings is likely to be an underestimate of the student time in training that can be saved. Further, even though this analysis assumes web-based capability for delivering the instruction, it does not take into account reductions in travel and temporary duty costs, which, if included, would further increase ROI. Finally, the administrative efficiencies, improved tracking and assurance of student progress, and other benefits provided by ADL technology – benefits that were not considered in the previous analysis – have their place and would continue to argue for its use.

Less time in school means more time on the job. Savings in time needed to reach training objectives not only reduce training costs, but also increase the supply of people for operational forces without increasing the number of people in uniform. Ways to account for accompanying increases in readiness and effectiveness due to force multiplication remain to be determined, but they, rather than savings in training costs, may be the most significant impact of reducing the time required by operational forces to reach performance levels.

In short, a significant return seems likely to result from an investment to convert some proportion of training to ADL technology. This value arises primarily from the reduction of student time spent in the training infrastructure. Even with ADL, seasoned military personnel must provide additional training, mentoring, and monitoring for people early in their careers. Certainly, efforts must be made to preserve the camaraderie and esprit de corps gained by students undergoing the rigors of training together. The argument for ADL is not to

suggest the massive replacement of people by the technology. It is, instead, that ADL reduces costs to train and increases force effectiveness by releasing people sooner from the training infrastructure and ensuring their competencies. A cost- effective, optimal balance between the use of ADL and more people-intensive approaches to training and education remains to be determined.

A.5.3 Performance Aiding

Most of the discussion to this point has focused on education and training applications using ADL technology. Something remains to be said about its use in providing on- demand performance aiding. The term Interactive Electronic Technical Manual (IETM) is a generic label for such a device [22]. Fletcher and Johnston (2002) [18] presented data on effectiveness and costs of several portable, electronic maintenance performance systems, one of which was the Integrated Maintenance Information System (IMIS).

IMIS was a wearable, computer-based performance aid for avionics maintenance. Thomas (1995) [45] compared the performance of 12 Avionics Specialists and 12 Airplane General (APG) Technicians in troubleshooting three F-16 avionics sub-systems. Within each of the two groups of subjects, six of the fault isolation problems were performed using paper-based Technical Orders (TOs) (Air Force technical manuals), and six were performed using IMIS.

Training for APG Technicians includes all aspects of aircraft maintenance, only a small portion of which concerns avionics. In contrast, Avionics Specialists must meet higher selection standards and receive 16 weeks of specialized training that focuses on avionics maintenance. Costs to train APG Technicians are about half the costs for Avionics Specialists. Table A-2 shows the results of the study.

Table A-2: Maintenance Performance of 12 Air Force Avionics Specialists and 12 APG Technicians Using TOs and IMIS.

Technicians/Performers	Correct Solutions (Percent)		Time to Solution (Minutes)		Average Number of Parts Used		Time to Order Parts (Minutes)	
	TOs	IMIS	TOs	IMIS	TOs	IMIS	TOs	IMIS
Avionics Specialists	81.9	100.0	149.3	23.6	8.7	6.4	19.4	1.2
APG Technicians	69.4	98.6	175.8	124.0	8.3	5.3	25.3	1.5

As shown in the table, findings of the study were as follows:

- **Avionics Specialists using TOs compared with those using IMIS** – The Avionics Specialists using IMIS found more correct solutions in less time, used fewer parts to do so, and took less time to order the parts. All these results were statistically significant. The results concerning time to order parts are to be expected because IMIS automated much of this process.
- **APG Technicians using TOs compared with those using IMIS** – The APG Technicians using IMIS found more correct solutions in less time, used fewer parts to do so, and took less time to order the parts. All these results were statistically significant.
- **APG Technicians using IMIS compared with Avionics Specialists using TOs** – The APG Technicians using IMIS found more correct solutions in less time, used fewer parts to do so, and took

less time to order the parts than did Avionics Specialists using paper-based TOs. All these results were statistically significant.

- **APG Technicians using IMIS compared with Avionics Specialists using IMIS** –The APG Technicians performed just about as well as the Avionics Specialists and even slightly better in the number of parts used. None of these comparisons were statistically significant.

The economic promise suggested by these results could well vanish if the costs to provide the performance aid (i.e., the IMIS) exceed the costs they otherwise save. Teitelbaum and Orlansky (1996) [46] estimated IMIS reductions in depot-level maintenance, organizational-level maintenance, and maintenance and transportation of inventories of spare parts. They found annual savings from the use of IMIS at about \$38 million for the full Air Force fleet of F-16s. They assumed an 8-year useful life for IMIS and estimated about \$18 million per year to maintain and update it and amortize its development costs.

The result is a benefit of about \$20 million per year in net savings or an ROI of about 1.11, which excludes the significant impact of IMIS on sortie rate, readiness, and operational effectiveness.

A.6 THE ADL VISION

The long-term ADL vision is an extrapolation from such developments as portable, increasingly accessible computing (including hand-held, worn, or even implanted computers), the global information infrastructure (currently manifest in the World Wide Web with its multifarious search engines), modular object-oriented architectures, Web 2.0 technologies, and natural language processing. The march toward devices that might be described as personal learning associates seems inevitable.

As currently envisioned, these devices will act as personal accessories. They will respond on demand to each individual's needs for education, training, and performance aiding by assembling relevant objects from the global infrastructure and engaging the user in guided conversations, such as those described by Hu, Graesser, and Fowler [30], to enhance user knowledge and skills and/or problem-solving capabilities. Learning in these cases is not a matter of just working through pre-specified lessons but is a return to the 100,000 year old tutorial practice of an individual and a sage working together to enhance knowledge and skill. In this case, the human sage is supplanted by a computational device that has access to something approaching the whole of human knowledge carried throughout the global information infrastructure.

As described Dodds and Fletcher (2004) [12] and by Wisher [50], objects drawn from the global infrastructure must be portable, durable, reusable, and accessible. Gallagher (in press) [24] discusses the history and development of the Sharable Content Object Reference Model (SCORM), which can ensure that objects have the first three of these qualities.

In addition, the objects must be accessible. As discussed in more detail by Lannom [33], the development of the Content Object Repository Registration/Resolution Architecture (CORDRA) and its use by the ADL registry provide global visibility for objects while allowing their developers to retain control over access to them. They are then available for reuse or repurposing.

These developments have provided ways for objects to be identified and collected for local use from the global information infrastructure. The continued operation of Moore's Law and the market-driven effort to imbue computer technology with natural language understanding should ensure development of affordable, mobile, conversation-capable computing. The major issue that remains for ADL is development of the envisioned

individualized tutorial capabilities. Progress and promise can be seen in this area (e.g., [28] and [30]), and it remains key for realizing the full ADL vision.

A.7 CONCLUSIONS

In short, the aforementioned research suggests that effective use of ADL technology:

- Increases instructional effectiveness;
- Reduces time needed to learn;
- Ensures that all students learn;
- Is preferred by students; and
- Is effective and efficient for distributing instruction anytime, anywhere.

Most of research and data to support these conclusions have been available for some time. The usual lag between research findings and their application in practice is observable here as elsewhere. As argued first by Fletcher (1992, 1997) [14], [15] and later by Corbett (2001) [8], ADL technology may make Scrivin’s educational imperative and Bloom’s tutorial instruction affordable.

The “Rule of Thirds” that emerges from empirical evaluations of technology-based instruction was mentioned earlier in this report. The Rule of Thirds is strictly a statistical statement. It summarizes a large body of empirical findings, but it does not directly address cause and effect.

An often quoted statement that “The best current evidence is that media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition” ([7], p. 445) does address cause and effect. This point of view seems both fair and unequivocal. The presence of any technology is no guarantee that effective instructional content, effective ways to present it, or even that the unique strengths of the technology itself will be present or used. On the other hand, the absence of technology, including ADL technology, is a reasonable guarantee that its unique functionalities will be unavailable.

Another statement to consider is that “If you don’t have a gadget called a ‘teaching machine,’ don’t get one. Don’t buy one; don’t borrow one; don’t steal one. If you have such a gadget, get rid of it. Don’t give it away, for someone else might use it. . . . If you begin with a device of any kind, you will try to develop the teaching program to fit that device” ([26] p. 478).

Gilbert seems both right and wrong. He is certainly correct in suggesting that instructional designers and developers who adapt a “teaching machine” will try to fit the teaching program to it. However, the new functionalities such a device makes available motivate its adoption and instructional adaptations to it.

It is less certain that such adaptations are to be avoided. They might well be enthusiastically sought, just as printed textbooks were sought long ago. If properly applied, technology should improve – if not revolutionize – the effectiveness and efficiency of teaching programs. It is up to researchers, developers, and instructors – not the technology itself – to see that it does.

Finally, there is the Columbus effect. In keeping with technologies that made carriages go without horses and telegraphs transmit without wires, the Columbus effect will doubtless apply to our efforts to provide tutorial instruction without humans. We envision the development of personal learning associates and are building

toward them. However, just as Columbus headed for the East Indies and ended up with something entirely unexpected, we may end up with something as unforeseen and different from horseless carriages and wireless telegraph as automobiles and radio. Nonetheless, making education, training, and problem-solving aids as affordable and universally accessible as possible seems as good a start as any.

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